Thoughts on Industrialization

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Industrialization – the JLab consensus view

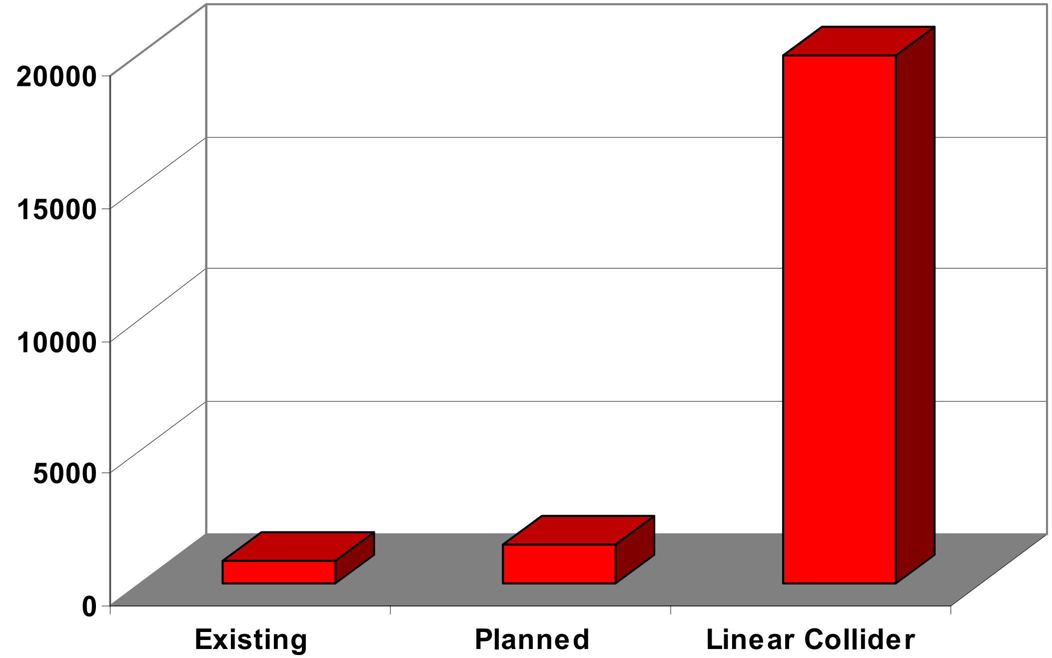
- Process that transforms an emerging technology into a commodity, i.e. vendors will exist who can deliver a complete ILC cryomodule to a performance spec (only a few labs can do this today). This will require:
  - Development of robust processing techniques
  - Production/manufacturing engineering for greater automation
  - Value engineering for reduced cost
- Manufacture and sale must result in profit for the vendor
- Demand predictability sufficient to support accurate 3-year planning. Absent a stable market, incentivization required.
- Must lead to functionally identical, plug-replaceable modules from multiple vendors
- Must be open to a process that yields an optimized design that may be significantly different from present concepts

Industrialization – what it is not!

- **Cookie-cutter solution for all regions and all vendors**
- **Industry-supplied components integrated by labs**
- **Achievable solely through large government (even international) projects**
- **Easy**

Elliptical Cavity Production - Reflections on Scale

- **Existing:**
  - **HEPL SCA, MACSE, S-Dalinac, HERA, TRISTAN, CEBAF, TESLA, SNS**
- **Planned:**
  - **Proton Driver, XFEL, various proposed ERL-based FELs**



- **Cavity numbers illustrate problem scale.**
- **Major industrial participation a must**
- **Capable labs need to make their infrastructure available to industry for development of SRF industrial capability**
- **Planned accelerator-based facilities must be used as an industrial development opportunity**
- **SMTF is a vehicle through which FNAL can direct/influence process**

Further Reflections on Scale: Skills & Facilities

- **Skills**:
  - Scientific (cavities, surfaces, RF, cryogenics, beams, materials, …)
  - Engineering (clean processes, mechanical, RF, diagnostics, computers, vacuum, …)
  - Technical Staff (electrical, electronic, RF, instrumentation, mechanical, vacuum, cryogenic, metrology, chemistry, assembly, alignment, …)

- **Facilities**:
  - Structure development (codes, RF labs, copper model shops, …)
  - Specialty fabrication (acid etching, brazing, sputtering, e-beam welding, Nb fabrication tools, new process deposition systems, …)
  - Cavity processing (clean rooms, high-pressure ultra-pure water rinse, particulate-free UHV pumping, emerging cleaning techniques and surface treatments, ultrasonic cleaning, …)
  - Cavity testing (clean assembly tooling, diagnostic instrumentation, RF controls and DAQ, …)
  - Materials and surface analysis (SIMS, SAMS, SFEM, TEM, SEM, XPS, MOM, profilometer, …)
  - Cavity string assembly (particulate-free UHV pumping, high-pressure ultra-pure water rinse, …)
  - Cryomodule component prototyping (quick turnaround cryomodule simulator - CECHIA)
  - Cryomodule assembly (parts staging, component welding, tooling, inventory management, …)
  - Cryomodule and RF controls testing – without beam (RF power & controls, cryogens, …)
  - Data and information management (procedure/traveler/database integration)

All of these are available somewhere in industry. The industrialization process must create one company capable of doing or managing them all with the objective of producing ILC cryomodules.

Do We Know What We Want Industry To Do?

In general terms, yes:

- Cavity production processes to achieve gradient (>35 MV/m) and Q_0 (> 5 x 10^9) established by the TESLA collaboration (~25% of cost):
- Satisfactory Fundamental Power Coupler design has been developed and demonstrated (25%)
- Cryomodule design developed and prototyped (50%)
- Build these to spec!
- Providing specific direction and robust, demonstrated processes still beyond our grasp; significant R&D required
- Intermediate projects (XFEL, PD) can get us part, but not all the way, to the goal

Substantial cost reductions are required to fulfill promises made in cost estimates! We need to go from building hand-crafted Lamborghinis to building Chevy Malibus, Hondas Civics or Opel Corsas. Design simplification a must!

How Ready are We to Begin Construction?

- Cavity construction sequencing is ‘traditional’, i.e. suited for low quantity production runs typical of R&D or small projects (100s, not tens of thousands)
  - TESLA collaboration has identified one equipment modification (use of a load-lock facility on the e-beam welder) that substantially increases throughput and reduces cost. Others will be found, if systematically pursued.
  - Cavity costs are about 25% of the cryomodule cost
- Fundamental Power Coupler requirements are demanding; the design is complex and relatively expensive.
  - FPC costs are about 25% of the cryomodule cost
- Cryomodule design is also ‘traditional’, i.e. not designed for mass production, assembly is complex and requires a lot of touch labor
  - 50%, most of it labor.
- Achieving linac production costs assumed in the various ‘estimates’ will require reductions from current US experience of a factor of ~4

- Not very

An Evolutionary Approach - I

- **Phase I**
  - Encourage the establishment of an industrial forum. These exist in Europe and Asia
  - Initiate a regional dialog with a well-publicized industrialization workshop
  - Set up SRF manufacturing development center(s) (MDC)
    - How many? One per region?
    - Define aggressive development program and objectives
  - Collaborate/contract with University centers for manufacturing R&D
  - Hire consultants on clean fabrication processes (feed into design of centers)
  - Exploit SBIR/STTR and CRADA mechanisms for maximum industrial participation at small scale
  - Court large companies
  - Small scale industrial involvement also through Industrial Fellowships? Service contracts?

Discussions between US labs and industry is initiated.
Opportunity for labs to generate community support.
Coordination with GDE is essential.
SMTF should play a leading role in this process.

An Evolutionary Approach - II

- **Phase II**
  - Execute aggressive development program in MDCs
  - Contract with industry for elements of development program (including program management?)
  - Exploit industry/university links to rapidly develop skilled manpower
  - Identify candidates for full industrialization
- **Phase III**
  - Procure pre-production prototypes from industry – several companies (parallel or leader-follower?)
  - Small scale production should now be going on in a number of places around the world. Make sure best results from everywhere are incorporated into the final design – need to deal with competition issues
- **Phase IV**
  - Place contracts for the first pre-production runs. Order from multiple companies in each region
  - Evaluate results of pre-production runs and issue follow-on production orders to best producers

Summary

- To achieve the full benefit of industrialization, labs must find and mentor companies capable of taking over the integration role – <u>then get out of the way!</u>
- Time is extremely short– need to get started <u>now</u> using approved and planned projects as industrial development vehicles
- Increase in scale and reduction in unit cost daunting: full industrialization is the only practical approach – be prepared and accepting of design changes that reduce production cost and increase production yield.
- US industrial development will require incentives

US labs have begun process, working through collaborations and partnerships. In the US program as presently understood, SMTF must be a leading participant.

Backup Material